Journal of Environmental Management 314 (2022) 114994

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Lessons from bright-spots for advancing knowledge exchange at the interface of marine science and policy

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ARTICLE INFO

ABSTRACT

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https://doi.org/10.1016/j.jenvman.2022.114994
Received 12 January 2022; Received in revised form 25 March 2022; Accepted 27 March 2022
Available online 19 April 2022

Keywords:
Research impact
Marine environmental governance
Science-policy interface
Evidence-informed decision-making
Transdisciplinary research

Evidence-informed decision-making is in increasing demand given growing pressures on marine environments. A way to facilitate this is by knowledge exchange among marine scientists and decision-makers. While many barriers are reported in the literature, there are also examples whereby research has successfully informed marine decision-making (i.e., 'bright-spots'). Here, we identify and analyze 25 bright-spots from a wide range of marine fields, contexts, and locations to provide insights into how to improve knowledge exchange at the interface of marine science and policy. Through qualitative surveys we investigate what initiated the bright-spots, their goals, and approaches to knowledge exchange. We also seek to identify what outcomes/impacts have been achieved, the enablers of success, and what lessons can be learnt to guide future knowledge exchange efforts. Results show that a diversity of approaches were used for knowledge exchange, from consultative engagement to genuine knowledge co-production. We show that diverse successes at the interface of marine science and policy are achievable and include impacts on policy, people, and governance. Such successes were enabled by factors related to the actors, processes, support, context, and timing. For example, the importance of involving diverse actors and managing positive relationships is a key lesson for success. However, enabling routine success will require: 1) transforming the ways in which we train scientists to include a greater focus on interpersonal skills, 2) institutionalizing and supporting knowledge exchange activities in organizational agendas, 3) conceptualizing and implementing broader research impact metrics, and 4) transforming funding mechanisms to focus on need-based interventions, impact planning, and an acknowledgement of the required time and effort that underpin knowledge exchange activities.

1. Introduction

Navigating the challenges facing marine social-ecological systems (cf. Berkes, 2017; Berkes et al., 2003) in ways that are sustainable and equitable requires the accessibility and integration of existing and newly emerging scientific knowledge into decision-making processes (Addison et al., 2018; Alexander et al., 2020; Fisher et al., 2014; Pendleton et al., 2019; Sutherland et al., 2004). The accumulation of information alone, however, is not enough to solve the complex and dynamic challenges facing marine social-ecological systems. Rather, it is crucial to improve the translation of marine scientific knowledge into action (Buxton et al., 2021), for example, through improved knowledge exchange (hereafter 'KE') among science and policy actors (e.g., Cvitanovic et al., 2016).

KE is a relatively new concept within marine management. In its broadest sense it implies a two- or multi-directional process of knowledge sharing with mutual benefits and learnings to both scientists and decision-makers (Fazey et al., 2013). KE therefore seeks to move beyond traditional linear models of science communication, which positioned researchers as the 'providers' of knowledge and decision-makers as the 'users' of knowledge, by recognizing the interdependencies between them (reviewed by Cvitanovic et al., 2015a). Over the past decade numerous approaches to improving KE at the interface of marine science and decision-making have been identified, including the process of knowledge co-production (Chambers et al., 2021; Norström et al., 2020) and the utilization of boundary spanning individuals (Cvitanovic et al., 2017; Lomas, 2007) or organizations (Bednarek et al., 2018; Cvitanovic et al., 2018; Meyer et al., 2015). For the purpose of this paper, and to be inclusive of all KE processes, we define KE as the interchange of knowledge between research producers and users, spanning all activities and processes of knowledge generation, sharing, storage, mobilization, translation, mediation and use (Best and Holmes, 2010; Cvitanovic et al., 2015a).

Despite growing recognition for the importance of KE, many barriers remain that limit the integration of marine science into policy and practice (Addison et al., 2015; Cvitanovic et al., 2015a). For example, barriers relate to the decision-making process itself (e.g., lack of time or expertise to search for, access and interpret scientific knowledge), cultural differences between science and policy (e.g., different 'languages'), institutional disincentives (e.g., publish or perish), and inadequate resources (time, money, capacity) (Cvitanovic et al., 2014, 2016; Rose et al., 2018; Walsh et al., 2019). Marine scientists often have the personal goal of impacting marine policy and management through their research, but few can report cases where they have achieved this (Cvitanovic et al., 2015b).

Clearly, there is still much to learn about how to effectively connect marine research with decision-makers and management. One step forward is by learning from 'bright-spots' - successful examples whereby marine science has informed policy and/or practice (Cvitanovic and Hobday, 2018). The importance of bright-spots as seeds of positive outcomes (cf. Bennett et al., 2016), as well as the meaning and diversity of impacts from successful KE are becoming increasingly studied and understood (Cooke et al., 2020; Cvitanovic et al., 2021a; Karcher et al., 2021). Broadly, impacts can be described as "changes in awareness, knowledge and understanding, ideas, attitudes and perceptions, and policy and practice" (Morton, 2015, p.36). It can span individuals, groups, organizations, societies, and ecosystems but are a matter of the context-specific perceptions of intended beneficiaries, as well as others who might be disadvantaged (Cvitanovic et al., 2021a; Reed et al., 2021). However, what constitutes success can vary across projects and perspectives – and evaluation of KE is challenging (Jagannathan et al., 2020; Meagher et al., 2008; Pitt et al., 2018; Posner and Cvitanovic, 2019). Increasingly, there are calls to more specifically plan for and acknowledge less tangible social outcomes like changed mind-sets, strengthened relationships, or resolved conflicts (Karcher et al., 2021; Louder et al., 2021). Accordingly, for the purpose of this study we define KE success as knowledge becoming:

> "accessible, understandable, shared, and used, enabled by good knowledge exchange products, - processes, and social outcomes […], with the potential to contribute to changes in policy and demonstrable societal impact" (Karcher et al., 2021, p.214).

However, more work is needed to understand the most promising pathways and the enabling factors to obtain such *successes*.

Learning from KE successes may help to build capacity for evidence-informed decision-making and equip scientists, decision-makers and practitioners with new ways of working together. Therefore, the aim of this study is to empirically identify, analyze and learn about improving KE from a broad range of marine science-policy bright-spots across different scales and marine ecosystems. We do this by addressing the following questions:

i) What initiated the project/initiative and what were the goals?
ii) Which approaches to KE were used?
iii) What outcomes and impacts were achieved?
iv) What were the enablers of KE success?
v) What lessons can we draw from them to improve KE at the interface of marine science and policy?

2. Methods

2.1. Recruitment of research participants

The Human Ethics Committee (Protocol 2020/693) at the Australian National University approved this study prior to data collection. We identified international experts in the field of marine science-policy interactions from a systematic review of the academic literature (as reported in Karcher et al., 2021). There was no individual rationale for each expert or their case study, rather a systematic identification process with self-identification of policy- or context-specific success by respective case study leaders. The lead author team (DK, CC, IvP, RC) checked studies from that body of literature for relevance to the scope of the present study (i.e., marine case studies at the science-policy interface covering KE interactions). If study focus and lead author research focus/background aligned, we contacted the lead author of each study, otherwise a different author on the same publication was contacted.

We contacted identified experts and asked if they were able and willing to participate. If so, they were asked to fill out a text-based survey with open-ended questions (Supplementary Material 1) (following approaches described in Kelly et al., 2019; Norström et al., 2020). Because literature in the field of environmental science-policy connections is predominantly produced by organizations from Europe and North America (Karcher et al., 2021), we actively took steps to overcome existing publication bias (e.g., geographical). Specifically, we sought to achieve a more balanced representation of global experts by asking the initial participants to identify other experts in the field (snowballing) and stopped when case studies from all continents and oceans were identified and included in the study.

In total, we contacted 49 potential participants, 33 of whom participated in the survey (67%) and joined this paper as co-authors (for some case studies, there was more than one expert contributor). Most participants played the role of a researcher within their specified case study (n = 14), followed by KE connector/organizer (n = 13) (including knowledge broker, boundary organization employee), or advising expert (n = 8). Some played more than one role and in five cases the identified experts were external to the KE process (e.g., involved as a policy analyst).

2.2. Selecting bright-spots

For the purpose of this study, we consider bright-spots to be situations when KE success (see *Introduction*) was achieved *and* marine research has had an impact (be it instrumental or non-instrumental) on policy and/or the practice of marine management (following Cvitanovic and Hobday, 2018). The included bright-spots were self-identified by the participants to account for individual notions to the perception of success where those involved know what met their needs and ambitions (Le Heron et al., 2021). We purposefully asked for bright-spots in which any research discipline (spanning both the social and natural sciences) has had an impact on policy and/or practice. To be considered for inclusion in this study, the bright-spots had to include actors from science and policy, and some also included actors from other stakeholder groups (e.g., fishers, NGOs, civil-, or boundary organizations). This process identified 25 bright-spots that span a wide range of ecological fields, marine spaces and policy scales (Supplementary Table 1).

An information-oriented selection of maximum variation case studies was followed (Flyvbjerg, 2006). The case study contexts and scales vary to generate diverse examples and lessons in the field. Most of the bright-spots focused on coastal waters, followed by national waters/exclusive economic zones (EEZs) as well as combinations of either coastal lands and waters, or coastal and offshore waters. Their governance level was mostly national, followed by local, regional (i.e., sub-national or state-level), and international (i.e., multi-national) (Fig. 1). In cases where bright-spots involved multiple levels we used the dominant level to characterize it for the purposes of further analysis. Among the 25 included bright-spots, 20 were based on completed projects, and five were ongoing. As per the criteria for inclusion in this study, projects that were still ongoing had to have already achieved some form of demonstrable impact/success related to KE. The starting

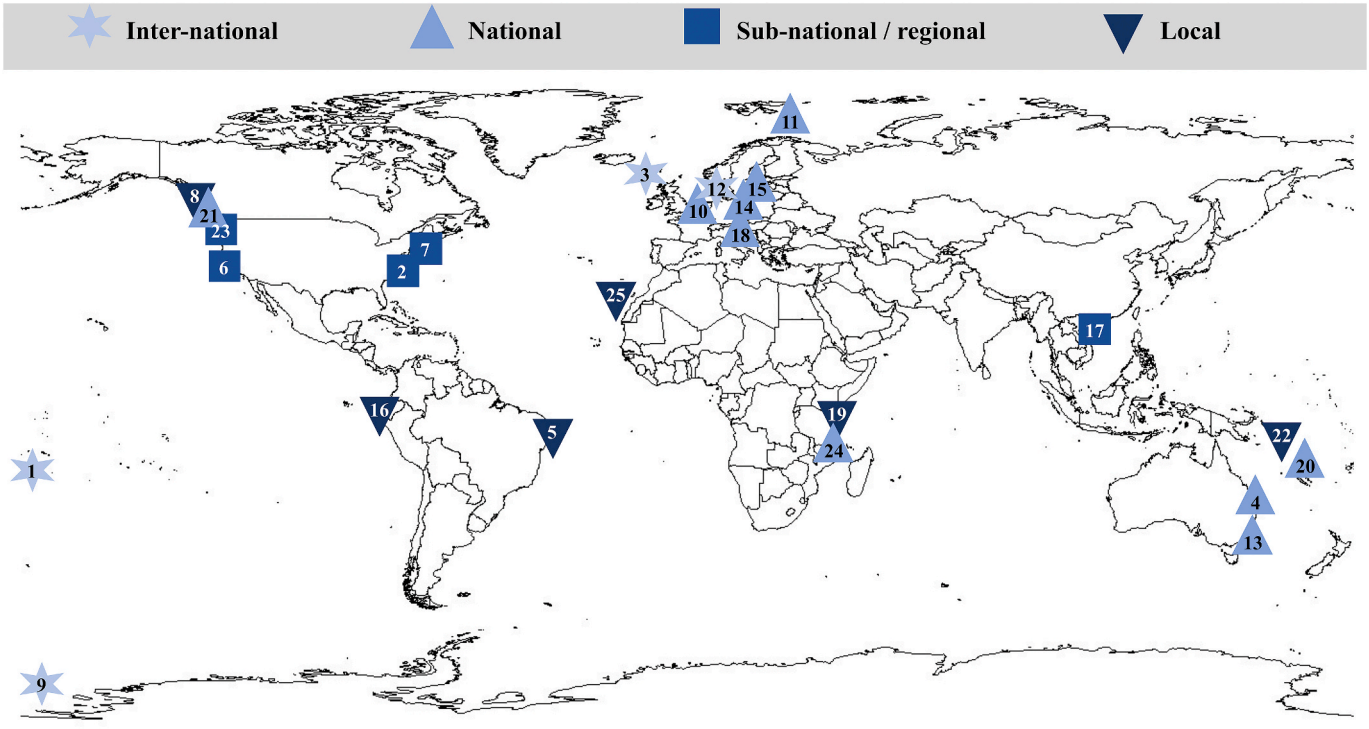

Fig. 1. Global distribution of marine science-policy bright-spots analyzed through this study, with international (✦), national (▲), sub-national/regional (■), and local (▼) governance level. Numbers identify the bright-spots (see Supplementary Table 1).

points of projects date back to the 1990s, but the majority (n = 16) commenced in 2010 or after, most recently in 2019.

2.3. Data analysis

Survey responses were analyzed using the qualitative data analysis software NVIVO 12. Following a grounded theory approach, *in vivo* inductive thematic coding was conducted for each research question with iterating theming of codes (Charmaz, 2006, 2008; Glaser and Strauss, 1967; Saldaña, 2015). The research questions embodied the starting points (i.e., broad themes like approaches, successes, enablers, recommendations) followed by an iterative, coding process within those themes. Hence, without additional pre-classification, the individual codes (using the participants' words) emerged directly from the data. As coding progressed, they were iteratively compared to existing codes to identify data-driven descriptive key themes (Blythe and Cvitanovic, 2020; Fleming and Vanclay, 2009; Saldaña, 2015).

To ensure inter- and intra-personal coding reliability, a randomly selected subset of three surveys was pilot-coded twice within four weeks by the lead author, as well as independently pilot-coded once by each for the four coordinating authors. We then met to discuss our individual codes and themes to identify overlap, and more importantly, points of divergence in our coding. Subsequently, three surveys were coded by two authors (DK, CC) and discussed to ensure coding reliability. A second cycle of coding was undertaken to find higher-level labels (i.e., broader categories), particularly for questions that had a lot of data themes. The data were reanalyzed following thematic coding to unravel coherent key themes (Saldaña, 2015). Emerging themes are reported in the results if they were raised by more than two bright-spots.

2.4. Methodological limitations

There are some methodological limitations associated with case study analysis that are important to note. Even though case-study research is well recognized for its contribution to understanding complex issues (see description of qualitative case-study research in Starman, 2013), the findings are not always directly generalizable across contexts. Thus, in presenting the results we acknowledge that the interface between marine science and decision-making varies between sectors, cultures, political systems, and governance levels. Thus, whilst the lessons we present are purposefully drawn from diverse case studies in diverse locations, settings, and levels to represent this range of contexts, they should be considered as guidelines rather than directly applicable to each context. While biases may exist in self-identification and self-reporting, this approach directly links to impact attainment in that impacts on policy or management were shown to be directly related to how 'successful' participatory transdisciplinary research is perceived (Steger et al., 2021). When discussing successes and their enablers within the bright-spots, we always refer to KE success, not a specific conservation success or impact.

3. Results

The coding of survey responses resulted in 1413 codes that were distributed across the main study goals and grouped together as themes. Themes are presented in order of number of sources (bright-spots, 'n') that mention the theme throughout the study. The frequency, which refers to the number of times each theme was mentioned by the participants (i.e., number of references), is presented in Supplementary Table 2.

3.1. Bright-spot setting (initiation, goals, approaches)

Data analysis revealed that the bright-spots had three main initiators or origins: i) policy demand (i.e., raised by policy processes or documents) (number of bright-spots (n) = 12), ii) research actors (n = 12), and iii) third parties (n = 11). Those third parties initiating the bright-spots were mostly funding agencies (e.g., funding requirement), but also NGOs, boundary organizations, or local or Indigenous communities.

The most common goals within the bright-spots were ambitions to impact policy (n = 17, particularly in national-level bright-spots) and create both scientifically and policy-relevant knowledge (n = 15). Other commonly reported goals included impact on governance (n = 12), social outcomes (n = 12), societal well-being (n = 9), and ecological well-being (n = 8).

A diverse range of KE approaches was used across the 25 bright-spots, which were classified into three overarching themes (Fig. 2): (i) activities (n = 25, i.e., specific actions such as events, meetings, collecting relevant knowledge, and connecting/facilitating/convening people and organizations); (ii) strategies (n = 24, i.e., broad concepts such as knowledge co-production, boundary work, and advisory bodies/agencies/assessments); and (iii) products used (n = 14, e.g., policy briefs or meeting papers). It is important to highlight interactions among these three themes. Altogether, convergent, collaborative spaces were important and one participant explained that their events (i.e., workshops) were structured to first "*open [ ] up a 'divergence' in terms of views and knowledge, and [then] create [ ] 'convergence'*". A full list of approaches, strategies, and products can be found in Supplementary Table 2.

3.2. Successes and impacts achieved in bright-spots

The successes most commonly identified were impacts on policy (n = 22). Reported impacts on policy included production of management/policy documents, the new formation of protected areas, and informed decision-making processes. Impacts on people was the next most commonly identified theme (n = 17), being relatively more common in regional-level case studies (Supplementary Table 3). Impacts on people included the expansion of social networks, relationships, trust, and mitigation of conflicts. It also included impact on individuals, for example, decision-makers (e.g., increased awareness and understanding of available and needed science), stakeholders or resource-users (e.g., increased recognition of other perspectives and/or conflicts) and researchers (e.g., learning about opportunities and roles of science and decision-makers). Individual impacts also reached more personal aspects as "*researchers had increased interest, confidence, and motivation to further engage with policy-makers*".

Other successes commonly identified were impacts on governance (n = 17, e.g., changed management processes, new monitoring/assessments, shift to ecosystem-based or community-based management) and 'relative' successes (n = 15). The latter include projects that went further and faster than anticipated, hit their own goals, or achieved something for the first time (e.g., management break-through after stagnation). For example, participants said that the project met their objective "*in full but at a more rapid rate than expected*" or managed to "*push the boundaries from what was initially anticipated*".

3.3. Enablers, lessons, and recommendations from global bright-spots

Participants identified five key categories of enablers (Table 1, Fig. 3): actors (n = 23), processes (n = 22), support (n = 16), contexts (n = 16), and timing and urgency (n = 13). Furthermore, participants made statements on the lessons from their project. Those referred to the importance of recognizing and including diverse actors and knowledge types (n = 11), considering time and effort (n = 8), and the nature of boundary work (n = 8).

The recommendations from participants to others working at the marine science-policy interface fell into four distinct levels: i) personal level (n = 16), ii) process level (n = 12), iii) external level (n = 7), and iv) interpersonal level (n = 5). Key considerations for maximizing the likelihood of success at the interface of marine science and policy are summarized in Fig. 4. Because both the scope and findings of enablers,

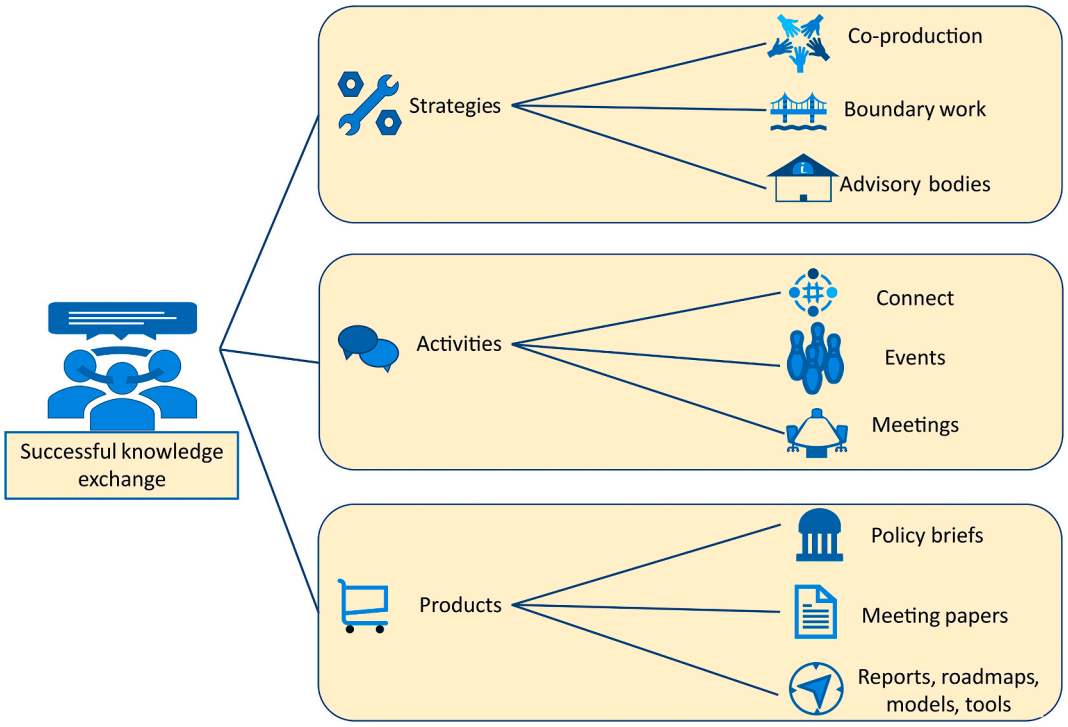

Fig. 2. Summary of the key approaches (spanning the strategies used, activities undertaken, and products produced across the 25 analyzed case studies) to achieving successful knowledge exchange in bright-spots at the marine science-policy interface.

lessons, and recommendations overlapped, they are combined here.

3.3.1. Actors

The actor group (i.e., all the people who were involved in the KE project) was a commonly discussed enabler of successful KE. Recognizing and including diverse actors and knowledge sources (research-based knowledge, experience-based knowledge, local, and traditional knowledge) was an important success factor. This was particularly important in bright-spots that occurred at local governance level (Supplementary Table 3) with one participant stating: "*When they [local people] are involved in developing the solutions, and this solution may help improve their wellbeing, their* support *may demonstrate as the determinant factor.*"

Actor-focused enablers also included the openness of the individuals (i.e., to co-learning, to collaborate, and to try new approaches), as well as having a devoted/motivated group of people. Trust, building on pre-existing relationships, and the relationships built between actors themselves, were also found to be key enablers, as were individuals who can openly and constructively debate conflicts, or have personal bonds/friendships between actors. One participant stated: "*Often personal relationships are overlooked for conservation; however, this is probably what made the key connections possible.*" Study participants suggested actively and deliberately building and facilitating trust, developing relationships, and socializing informally: "*It's about developing relationships between decision makers and researchers that allow them to explore and produce solutions together.*" The study participants also reflected that it takes a long time to build trust, as one participant said: "*The trust generating processes needed to be complex to include all the interest groups involved. And in some cases the level of initial mistrust was high and the process of overcoming that took quite some time (i.e. years).*"

At a personal level, actors' awareness of the diverse perspectives, roles, and limitations was another enabler of successful KE. This included being aware of the motivations, goals, and restrictions (e.g., institutional limitations) of others, particularly of decision-makers, as well as being aware of one's own and science's role. This was emphasized by two participants who said that "*technical research is only one factor among many that decision-makers must consider*" and hence the "*key lesson is to respect the restrictions on the policy side, which were not always transparent to [them]*". Other personal recommendations included the need for scientists to focus on decision-relevant questions, to be prepared (e.g., for a policy window), culturally and politically sensitive, supportive, humble, adaptive, and flexible, as well as not to rush or push too much. The personal factors also referred to the involvement of key individual champions/facilitators with specific skills or backgrounds. For example, that someone "*was born and raised in a fishing community, and as a consequence had a deep understanding of the constraints linked to the establishment of protection measures for fishers*". Furthermore, it included individuals' personal drive, contribution, and reputation. One participant said that "*the most significant factor was the personal commitment (indeed voluntary work sometimes) of the people involved*". This suggests that a lack of institutionalization/resources (e.g., to cover the full workload) may also occur in bright-spots, but underlines the high individual commitment, "*interest and drive*" to contribute towards a bigger change.

3.3.2. Processes and support

Within this theme, methodological enablers were most commonly discussed. These included the process being co-developed, the availability of clear, credible, decision-relevant research ahead of management, mandates by, or close collaboration with, authorities and policy bodies, as well as use of specific products or creative strategies (e.g., science-policy speed-dating) to support KE efforts. Such enablers were particularly relevant to bright-spots at international and regional scales (Supplementary Table 3). Recommendations relating to the process included explicitly establishing a collaborative science-policy interface (i.e., open spaces and minds where projects can be co-developed among diverse actors), and having timely and strong feedback loops among project participants to enable shared learning and local community empowerment. This is well-illustrated by one researcher's recommendation to other researchers conducting KE projects (i.e., knowledge co-production): "*Make communities a part that is at least just as relevant as your own research* agenda *[…] keep them in the loop, but always give them a*

Table 1
Coding structure of emerging themes distributed over the research questions of enablers, lessons, and recommendations. Listed are the number of bright-spots naming emerging themes (n) and brief descriptions of each theme.

Enablers	n	Description
Actors	23	
Interpersonal	18	The quality of interactions between people - relationships, bonds, and trust between individuals.
Actor group and openness	18	References made to the group of people as a whole - the team, team composition, devotion, and skillsets.
Personal	15	Characteristics, roles, backgrounds, and skills of individuals – facilitating role, commitment, reputation.
Understanding expertise, differences and restrictions	3	Referring to situational awareness regarding included actors – understanding roles, differences, and limitations.
Processes	22	
Methodological	20	Factors related to strategies and approaches as well as methodological inputs to the interaction (e.g., research quality, collaborative setting).
Process characteristics	8	The quality, flexibility, transparency, and relevance of the process.
Support	16	
Financial	11	Funding, financial support and flexibility, as well as financial incentives or benefits through the project/initiative.
Political	8	Broad (political) or specific (politician) supportiveness, demand, and receptiveness.
Public attention and support	6	Media attention, storytelling, celebrity support, (public) pressure, advocacy.
Organizational	5	Referring to organizations' institutionalized support, trainings, teaming-up and partnerships, but also their independence.
Contexts	16	
Background (e.g.,governance system and level)	14	Embracing the political context, governance system, scale, location, global context, as well as research background and previous work.
Local community	7	Local leadership and support, community organization and governance culture, and homogenous cultural/religious identity.
Timing and urgency	13	
Timing and opportunity	10	Referring to both the right timing (policy window), momentum, and opportunity for achievements, as well as persistent, continuous effort and punctual delivery.
Topic, need, urgency	8	Urgency of the issue as a hot topic with high social-ecological relevance.
Lessons learnt		
Recognize and engage diverse actors and knowledge types	11	Legitimacy and inclusion matter, stakeholders and local people/ communities should be engaged, as well as local, traditional, and experience-based knowledge.
Consider time and timing	8	Boundary work needs time, effort, resources, and the right timing.
Boundary work and context	8	Boundary work can be successful, but is often hidden, iterative, a sum of actions in a system of positive efforts and conditions.
Value people and relationships	6	References were made that it's all about relationships and bringing the right people together (i.e., human factors and investing in them).
Expect challenges along the way	5	Disruptions may occur, needs may change, research may be used for a political agenda or to delay action.
Accept that politics matters	4	Organizations have different mandates; different actors have different motivations; diplomacy and geopolitics matter.
Invest in trust and consistency	3	Trust is slow and difficult, it is individuals that build and break trust, and a clear and transparent policy process is key.
Focus beyond only science and policy	3	Focus on 'science' and 'policy' may be too narrow, society and public debate matter.
Governance context (different types of governance may work)	3	References were made that top-down approaches can or can't work (underlining context specificity).
Recommendations to others		
Personal	16	Recommendations to individuals, skills, roles, and behavior. For example, to be aware of perspectives and context, decision relevant, prepared, culturally & politically sensitive and supportive, humble, adaptive, flexible, and willing to compromise.
Process	12	Recommendations at process level, incl. strategies. For example, to install a truly collaborative interface with different societal actors and knowledge types & timely feedback loops among actors, empower locals, plan early, feasible, and target driven.
External	7	This includes recommendations to team-up with other organizations (incl. civil society organizations and advisory agencies) or boundary spanners, and train others.
Interpersonal	5	Relating to the interactions between individuals. This includes to facilitate trust, develop relationships, ask peers for feedback, network and socialize informally.

voice."

Data analysis also identified the need to 'start early' (acknowledging the time needed to establish collaborative research efforts with diverse stakeholders) and find the right policy windows, as well as focusing on what is feasible (i.e., what policy impact is realistic). Additionally, high flexibility and adaptability were valued, as highlighted by this statement of a participant: "*We adapted as we went, went down new pathways and could not, on Day 1, have predicted or scoped the […] outputs that were ultimately developed. This flexibility was really important.*"

Other process- and support-related enablers included the need to 'team-up' (e.g., with other organizations, civil society groups, or NGOs), to train others (e.g., students, stakeholders), and use/assist local authorities or advisory agencies in producing policy-relevant advice. Regarding the latter, one participant stated that "*it is essential to work through the regional technical agencies that national policy makers look to for advice*". An additional layer of support referred to the political supportiveness that projects benefited from. First, it refers to political supportiveness: "*The direct interest and involvement of the political class in the project was a game-changer and helped navigate through.*" Second, this refers to organizational-level support and institutional architecture around KE, with one participant saying that it was particularly enabling to work "*in a university-based boundary organization, with close support from communicators and a journalist, and after a while, also policy analysts*". Ultimately, participants emphasized that KE is more than a relationship between only 'science' and 'policy'. This is reflected by one participant having experienced "*a reality where that line [between science and policy] is usually blurred and where these categories might be too narrow*" suggesting "*there may be value in downplaying the science-policy dichotomy*". As such, a clear finding is that successful KE projects between research and *policy* (see *Methods*) also meaningfully engage *society* as a whole.

3.3.3. Context

Context was also commonly identified as having played a key role in

Fig. 3. Summary of the factors that enabled KE success in the 25 marine science-policy bright-spots analyzed in this study.

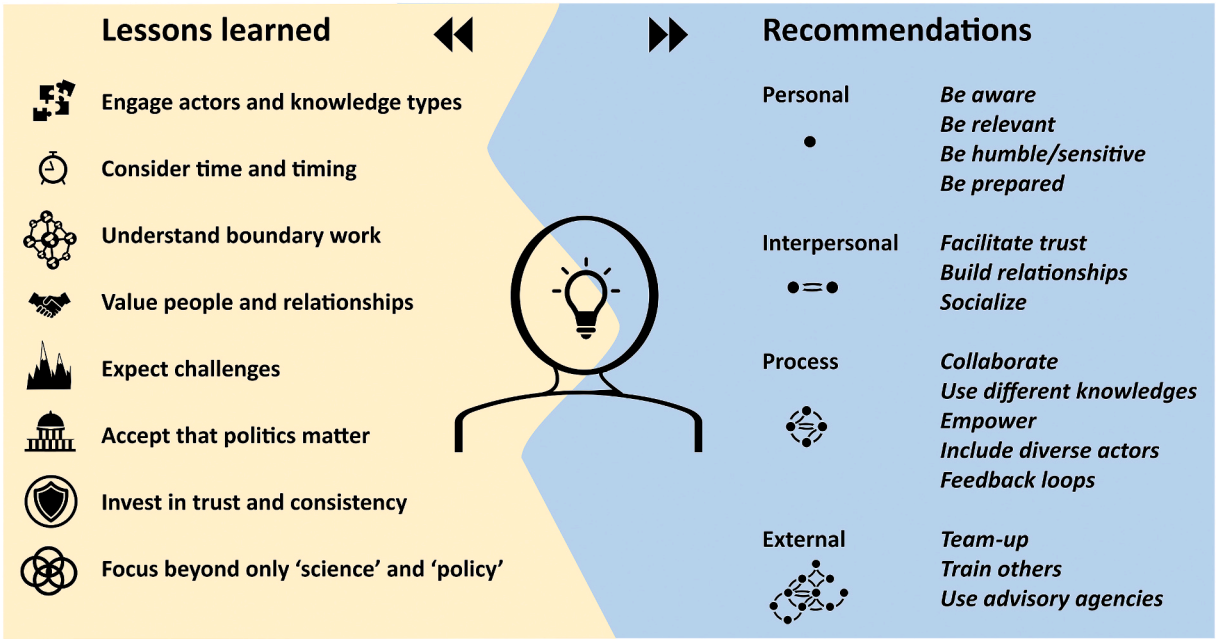

Fig. 4. Lessons (left), and recommendations (right) from participants in marine science-policy bright-spots to other researchers and practitioners conducting knowledge exchange.

enabling successful KE. Firstly, this refers to social and political background ranging from crises, court sentences, and the history of resource management to being "*embedded in a long-term political process*" (be it locally or internationally). Context included local preconditions to the engagement of non-academic actors, or a broader public "*tradition for appreciating knowledge-based policies*". More broadly, one participant reflected that "*successful initiatives are built on or embedded within other successes and long-standing relationships, and that they are a part of a broader 'ecosystem of positive efforts'*". Additional lessons were articulated around the governance context and roles of politics - for example, that relationships and motivations may reflect organizational mandates. On top of that, a small spatial scale was stated supportive to KE. Within

small spatial scale, a high level of local or traditional organization, leadership and governance culture supported successful KE (Supplementary Table 3).

3.3.4. Timing, urgency, and effort

Finally, time, timing, and opportunity were identified as important enablers. This is highlighted by one participant who said that "*a policy window facilitated state legislative action*" and another who explained "*[the project] came right at the time where poor conditions across all metrics (environment, economic and social) saw people willing to make a change to improve things*". The latter illustrates that the timeliness ('hot topic') of projects was often explained by local, strong dependence on marine resources threatened by poor ecological conditions. Findings also included the realization that successful KE takes a lot of time and invisible effort: "*Our experiences within a boundary organization suggest that the amount of time, resources and effort needed at the science-policy boundary are rarely recognized or given due credit.*"

4. Discussion

4.1. Bright-spot setting (initiation, goals, approaches)

Within the 25 marine science-policy bright-spots analyzed in this study, most were initiated by policy demand, donors, local communities, or boundary organizations. This mirrors Steger et al. (2021, p.7) who found that "projects initiated by practitioners [incl. policy-makers] and/or other stakeholders had a larger proportion of high policy impact compared to projects initiated by researchers only". While it was beyond the scope of this study to determine the reasons for this, it could be that academia is at times disconnected from policy-makers' needs, or that the non-research actors are more tightly and more timely connected to policy, ensuring relevance (Breckwoldt et al., 2021; Goldman and Pabari, 2021; Rose et al., 2020).

Relatedly, working with established advisory bodies or governmental agencies supported successful KE. The important role of advisory bodies and assessments, meaning the mandated generation, structuring, provision and debate of knowledge to inform decision-making on policy-relevant questions in a credible and legitimate manner (Adelle and Weiland, 2012; Deelstra et al., 2003; EEA, 2001; Hugé et al., 2011; UNEP and IOC/UNESCO, 2009), has long been known (e.g., Hoppe, 2010; Jasanoff, 1998; Soomai, 2017). Walsh et al. (2019) have also found formal collaborations with management organizations to be supportive to KE, because policy-makers find research conducted or commissioned by their own agency more relevant than external scientific research (British Academy, 2008). Designing agency-led projects with iterative elements between KE actors throughout the process may help ensure that needs are incorporated in the knowledge production to make the final results more policy-relevant and account for their experience-based knowledge that Sander (2018, p.114) called "traditional managerial knowledge".

The activities to achieve KE goals mirrored those commonly associated with boundary spanning and knowledge brokering (Bednarek et al., 2018; Lomas, 2007; Michaels, 2009). The most described strategy was knowledge co-production, an approach with a range of theoretical lenses (Bremer and Meisch, 2017) and practical modes (Chambers et al., 2021). The diversity of bright-spot approaches included many different co-production components at different points in time (co-designing, co-creating, co-writing, co-evaluating). What co-production processes have in common is helping political receptiveness and research uptake by being context-based, pluralistic, goal-orientated, interactive and benefiting from iterations among actors (Lemos and Morehouse, 2005; Norström et al., 2020).

4.2. Successes of KE

Results show that success at the interface of science and policy-making can be achieved, and that success comes in diverse forms and can be defined more broadly than traditionally conceptualized (supporting recent work by Cooke et al., 2020; Cvitanovic et al., 2021a; Karcher et al., 2021). Leaving bias from study selection criteria towards impact on policy/governance and comparison considerations aside, nearly 200 out of 326 references were made to other types of success. Among them were impacts on people (i.e., researchers and non-academic partners). For example, individual changes in knowledge or job satisfaction can occur (Cvitanovic et al., 2018, 2021a; Xavier et al., 2018) as well as individual learning and understanding of issues and uncertainties, or changes in attitude and practice of KE actors (Knapp et al., 2017; O'Connor et al., 2019). As a result, individuals may also have improved individual networks and reputation (Cvitanovic et al., 2021a), and ultimately gain more career opportunities (Hegger and Dieperink, 2015).

4.3. Enablers, lessons, and recommendations

Cvitanovic et al. (2016) identified three core capacities to enable KE, which are individual, institutional and financial capacities. In our study, factors related to people (i.e., interpersonal factors, actor group, individual enablers) were the most recurring enablers (throughout both individual and organizational KE endeavors). This refers to the actor group, its diversity, skillset, and devotion, corroborating findings by Cvitanovic et al. (2018) and Reed et al. (2014). Beyond that, understanding the expertise, motivations, and limitations of all actors was paramount, mirroring the literature (Brugger et al., 2016; Cvitanovic et al., 2016; Evans and Cvitanovic, 2018; Marshall et al., 2017). Our findings underline the pivotal roles of building and maintaining trust and long-term relationships (Balvanera et al., 2017; Cvitanovic et al., 2021b; Lacey et al., 2018; Newig et al., 2019; Tinch et al., 2018) suggesting that their attainment is of inherent value for KE. Hence, trust is critical as both an input and an outcome of successful KE. This relates to the notion of social capital as a "set of values and relationships created by individuals in the past that can be drawn on in the present and future to facilitate overcoming social dilemmas" (Ahn and Ostrom, 2002, p.3). Our study participants indicated that KE particularly benefited from pre-existing relationships, which corroborates the value of history (e.g., individual experiences, social capital and trust) around KE (Hakkarainen et al., 2020; Karcher et al., in review).

A clear finding was that, even when (by study-selection) focusing on marine science-*policy* interfaces, many other *societal* actors and knowledge types, beyond the domains of 'science' and 'policy' were engaged in the bright-spots, mirroring a new knowledge-governance interface recently proposed by Turnhout et al. (2021). This highlights the value and need for strong collaboration between natural and social sciences and humanities for KE and marine management (Mazé et al., 2017; Nogueira et al., 2021; Singh et al., 2021). Social sciences, including anthropology, law, and economics, have important contributions, for example in giving advice on what type of policy instruments may affect people - whose activities affect the oceans (Lascoumes and Le Gales, 2007; Sander, 2018; van Putten et al., 2021). In that regard, experience-based knowledge by both decision-makers and stakeholders also needs to be considered (Fazey et al., 2006; Stephenson et al., 2016). Practically, this leads to recommendations to early and meaningfully involve diverse actors and knowledge systems (Hegger et al., 2012; Tengö et al., 2014; UNEP and IOC/UNESCO, 2009; Weichselgartner and Kasperson, 2010). It is well-known that participation and integration of local or traditional knowledge are beneficial to research, knowledge use in decision-making and management, and conservation success (Dawson et al., 2021; Loch and Riechers, 2021; McKenzie et al., 2014; Raymond et al., 2010). Particularly on a local level, participants often made the recommendation to meaningfully include diverse knowledge types and empower local communities. This also requires making local and traditional knowledge more visible and useable and pursuing social equity in and through marine conservation (Bennett et al., 2021).

Although not directly interrogated by the survey, the governance level of KE projects emerged in the analysis as an enabler and point of differentiation between projects (Supplementary Table 3). Despite the fact that particularly the national and sub-national levels are favorable for science-policy work (i.e., for public awareness and shaping the implementation of legislation, Jensen-Ryan and German, 2019), we showed successful KE projects at different levels. Regional bright-spots exhibited the most diverse success categories, although we acknowledge the non-representative sample. On the other hand, an international level may facilitate dealing with overarching issues that take longer to enter in the national policy agendas. Overall, the time and timing were important success factors, referring to the recommendation to proactively analyze and tackle emerging issues early-on (UNEP and IOC/UNESCO, 2009). Our findings corroborate Rose et al. (2020) in that KE is facilitated when evidence is synthesized and interpreted in a management-relevant way before a policy window opens, and that effectiveness increases when solutions are prepared ahead of time.

4.4. Limitations and future research opportunities

The study of bright-spots has high potential to inform how KE at the interface of science and decision-making can become more successful, but it also comes with methodological limitations. Firstly, as indicated in the *Methods* section, this case study cannot easily be generalized. It has to be considered that culture and openness are key to research use in policy-making (Court and Young, 2003; Goldman and Pabari, 2021), and that interactive engagement is a matter of cultures of participation (Reed et al., 2018). For project settings (e.g., initiation, strategies), we are unable to discern whether these co-exist with success or contribute to it. Therefore, in this study, we intended to look across very diverse case studies (i.e., breadth of data) to show commonalities despite the diversity of approaches and not to deep-dive into a specific case. Secondly, approaching bright-spots brings forth the limitations of binary approaches (success/not success) in that projects with other ambitions could be easily disregarded as a failure (cf. Giakoumi et al., 2018). To address this, we have transparently described the full study selection process including its ambition and have based it on participant-identified success.

A track for future research on marine science-policy bright-spots could be analyzing the perceptions of more actors. Here, we mainly targeted well-connected, frequently-publishing researchers potentially missing out on experts immersed in a limited number of projects, but more deeply (many KE practitioners do not publish in academia). It also refers to non-academic actors involved in KE. Including them would ensure a more holistic presentation of perspectives beyond individual experiences of researchers, given that success, as well as the paths towards it, are a matter of perspective (Jacobs et al., 2005; Parker and Crona, 2012; Reed et al., 2021). KE work is only one of the contributors to changing policy, but there are many other actors and factors affecting it, making it hard to establish causality from KE initiatives (Ferguson et al., 2016). Moving forward also requires combining empirical bottom-up approaches and theoretical developments to understand how the factors for a successful implementation of KE causally relate to each other. What are the critical factors, how can they be measured, what trade-offs may exist and how do they affect success? Ultimately, a better – more causal – understanding is needed on which success factors can be traced back to the institutional architecture supporting KE activities. Future studies should both consider the diversity of approaches in individual cases to engage more with specific contexts, but also develop broad indicator frameworks that allow achieving and assessing KE success across different cases and contexts.

5. Conclusions: mainstreaming marine science-policy bright-spots

Having shown that diverse successes at the interface of marine science and decision-making can be achieved and enabled by the right people, methods, levels of funding, and timing, we would like to reflect on some of those themes, and what they mean in terms of making bright-spots the norm, not the outlier. First, we emphasize that positive examples of KE success exist across diverse governance levels and marine ecosystems. Accordingly, this work might motivate others to take the path of interactive KE, or as one participant phrased it: "*Do not be afraid of politicians; they do not bite. When they do, please direct them to bite the right place and remove barriers.*"

Second, our findings suggest that there is a need to diversify training opportunities to conduct KE well. Although society-relevant research is important and often appreciated, we acknowledge that interactive KE may not be everyone's ambition and is often not considered in research planning. It is also apparent that those interested need help to develop a broader set of 'soft' skills to engage in KE (Bednarek et al., 2018; Pietri et al., 2013). Different components have been described to improve capabilities and capacities for KE via organizations (e.g., universities). At a small scale, they include the formalization of transdisciplinary working groups (including real-life labs, Bergmann et al., 2021), supportive supervision, and KE mentorship (Andrews et al., 2020; Cvitanovic et al., 2015b; Lyall and Meagher, 2012). Such mentorship and supervision should not end with theoretical advice, but also include the introduction to existing networks and collaborations to both form the skills needed and some of the 'pre-existing relationships' supportive to future KE success. This also includes guidance for early and mid-career scientists to be connected to those with more established careers and networks. Furthermore, good communication skills can be cultivated by organizations and university programs. On a larger scale, this challenge can be addressed by courses (e.g., mainstreaming 'human dimensions' into biology/conservation courses), fellowships, internships, student-led activities, and partnerships between universities (Duchelle et al., 2009; Lyall and Meagher, 2012; Rozance et al., 2020).

There is also a need for the institutionalization of KE within organizations. Our data does not allow statements on how innovative research solutions and KE processes were for organizational or non-research-initiated KE compared to 'only' science pushing. However, our research has shown that working at the science-policy interface in an organized manner – through advisory bodies, boundary organizations, or NGOs – is conducive to KE success. This may require clearer institutional arrangements, relationships, and responsibilities (UNEP and IOC/UNESCO, 2009). To that end, resourcing, and institutional/cultural commitment to support relationship building and offering the time this takes are critical. Such resourcing and organizational support may need organizational re-examination of agendas, norms and constraints (Pearman and Cravens, 2022). The importance of human factors, people's skills and drive towards achieving success not only shows the role of interpersonal relationships but suggests that there is a shortage of formal, institutionalized KE arrangements. Research and funding organizations should consider KE as part of their mission, allocate required resources, positions, and recognize the value of KE work. From an organization's lens, this may include 'cross-learning' initiatives (e.g., workshops and/or residence type arrangements between academic and non-academic institutions to increase the understanding of each other's operating contexts) or transdisciplinary programs (e.g., EU COST program, https://www.cost.eu/). Currently, not only researchers but also practitioners in, for example, NGOs or boundary organizations, have to explicitly promote KE and justify its budgeting.

Trust and existing relationships are also key but the time and skills to build them are not usually captured by traditional metrics of research impact (i.e., publish or perish culture, citations, etc.). This is exemplified by institutional incentive structures and funding being the major barriers to KE, likely creating trade-offs between KE success and academic success (Shanley and López, 2009). We therefore call for a shift in the measures of science impact and institutional innovation (Cvitanovic et al., 2015b; Sellberg et al., 2021). Given the role of flexible and supportive funding, one pathway for change lies in the hands of funding

bodies that can affect research, its planning, conduct, and impact (Arnott et al., 2020; Lyall et al., 2013; Trueblood et al., 2019). Accordingly, we encourage institutional changes in both research institutions (e.g., institutionalization of KE, training, science-society connections) and funders (e.g., through targeted impact planning, acknowledgement of time and resources needed for KE) to remove KE barriers, and create the conditions (including the right people, skills, and processes) required for bright-spots to become more common.

Author statement

Conceptualization: DK, CC. *Methodology*: DK, CC, IvP, RC. *Formal analysis*: DK, CC, IvP, RC. *Investigation/data*: DA, SA, MB, NB, MBP, AB, JB, CB, TD, RCM, TF, EF, AH, DH, CH, TJ, AK, MKK, ML, PL, PM, AMG, EKM, PN, JPF, SP, HR, KS, GS, DS, PT, EW, JZ. *Writing - Original Draft*: DK, CC. *Writing - Review & Editing*: all authors. *Project administration*: DK. *Supervision*: CC, IvP, RC.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

We would like to thank Rebecca Shellock for her support with the sampling method, and Aislinn Dunne for the fruitful discussions. We thank Gun Rudquist for her contribution regarding bright-spot 15. PFML thanks CNPq for a productivity grant (301515/2019-0). DJS has funding support from the Australian Government through project ACIAR FIS-2016-300. TJ and JZ gratefully acknowledge financial support by the German Federal Ministry of Education and Research (Grant No. 01DO17018) is gratefully acknowledged. AMG is supported by the UK Natural Environment Research Council (NE/R002738/1) Knowledge Exchange fellowship scheme and the EMFF-funded NEA PANACEA project (110661/2020/839628/SUB/ENV.C.2.RWS). DA and EKM are supported by the Social Sciences and Humanities Research Council of Canada. NCB was supported by the Natural Sciences and Engineering Research Council of Canada. PCM was funded by the EU LIFE Euroturtles project (LIFE15 NAT/HR/000997). RCM was funded by the Fundación CajaCanarias and Fundación Bancaria "La Caixa'' [grant number 2017REC23], as well as the Ramón Areces Foundation for their support via their Social Research Grants [grant number CISP17A5887].

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2022.114994.

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